MPD Multi-π Exclusive Samples

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Fermilab

Two Param Reco Approaches – a reminder:

Edepsim parametrized reco:

- Used old physics FD TDR-geometry (done by Tanaz, Justo, Chris M.)
- Used edepsim instead of GEANT4

TEA (Tanaz, Eldwan, Andy) parametrized reco:

- Uses new ND CDR-geometry
- Includes rock interactions and overlays samples
- Uses full GEANT4 simulation

Two Available Parametrized Reco

- Edepsim parametrized reco:
  - ν-interactions on Ar using GENIE & the optimized flux files from Nov. 2017 + detector model using edep-sim + some relatively outdated geometry
  - HPgTPC: uses Gluckstern to parametrize/Gaussian smear particle momentum for tracks in HPgTPC
  - LAr TPC: Gaussian smears particle momentum in LAr TPC by 14%

- TEA parametrized reco:
  - ν-interactions on Ar, ECAL, passive components of MPD, rock surrounding the near detector hall using GENIE & the optimized flux files from Nov. 2017 + detector model using GEANT4 + new CDR geometries
  - HPgTPC: uses Gluckstern to parametrize/Gaussian smear particle momentum for tracks in HPgTPC and for tracks that stop TPC, uses a range-based approach to Gaussian smear the momentum
  - LAr TPC: TEA is not yet a module that gets integrated with LAr TPC since LAr TPC parametrized reconstruction is not yet developed

Pros and Cons

- Advantages of edepsim (since this talk primarily focuses on use of edepsim param reco for exclusive MPD channels):
  - Only framework known to this point that includes **an integrated LAr and GAr reconstruction**
  - Already being used extensively by the LBL group and S. Jones has been doing great work using these samples: https://indico.fnal.gov/event/23440/contribution/2/material/slides/0.pdf

- Caveats of edepsim:
  - Original version of edepsim parametrized reco needed a lot of improvements to ensure apple-to-apple comparisons between MPD and LAr TPC
    - My changes to the original module:
      - Introduced a 2 cm threshold in LAr TPC
      - Changed HPgTPC threshold to 2 cm
      - Integrated approach in neutrino energy reconstruction in both TPCs (adding energies of FS particles event by event)
      - Realistic counting of pions in both TPCs

Momentum Resolution

- Both parametrized recos use the same smearing approach: smear p_{true} using the σ_p in the Gluckstern formula
- For stopping tracks, TEA uses range-based momentum smearing (not implemented in edepsim param reco)

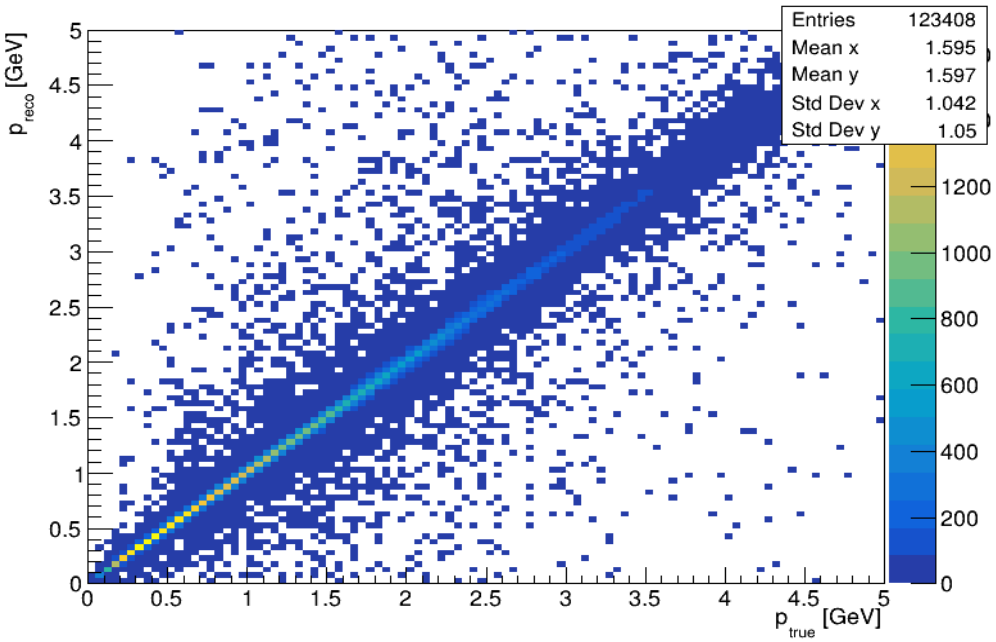
Measurement Term

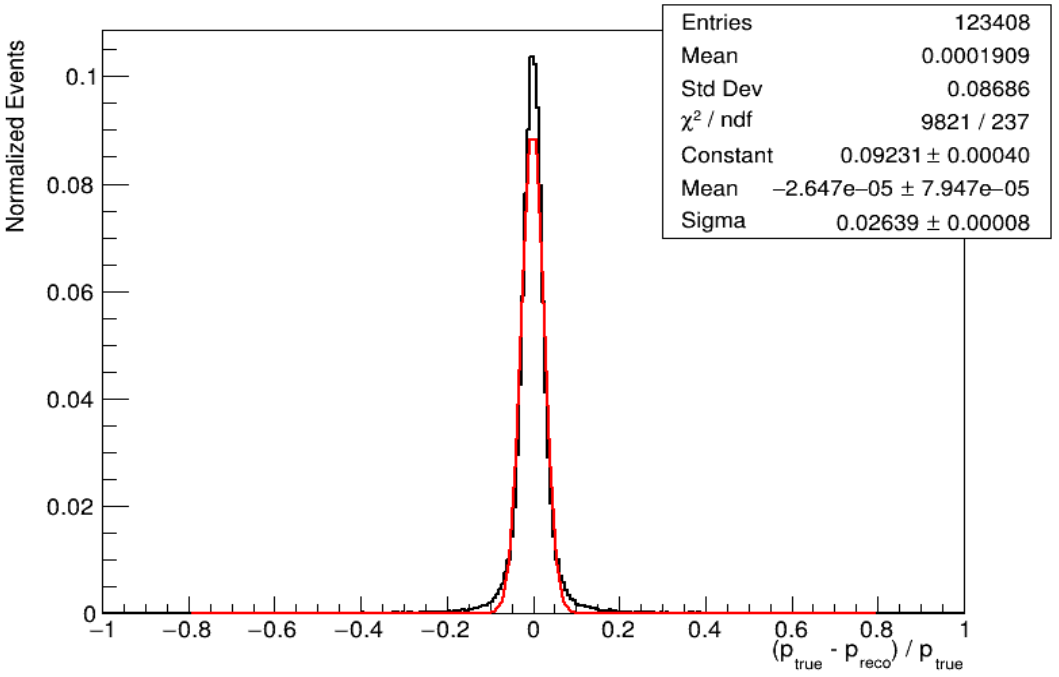
$$\left(\frac{\sigma_{P_\perp}}{p_\perp}\right)^2 = \left(\frac{\sigma_{\text{point}}\ p_\perp}{0.3\ B\ L^2}\sqrt{\frac{720}{N+4}}\right)^2 + \left(\frac{0.05}{B\ L}\sqrt{\frac{1.43\ L}{X_0}}\right)^2$$

Scattering Term

σ_p: 1e-3 m (distances between the readout pads)
B: 0.4 T
N: # of trackpoints (tracklength over distance between pads)
L: tracklength $\perp$ to beam direction
X_0: 13 m

primary μ true vs param reco kinematics

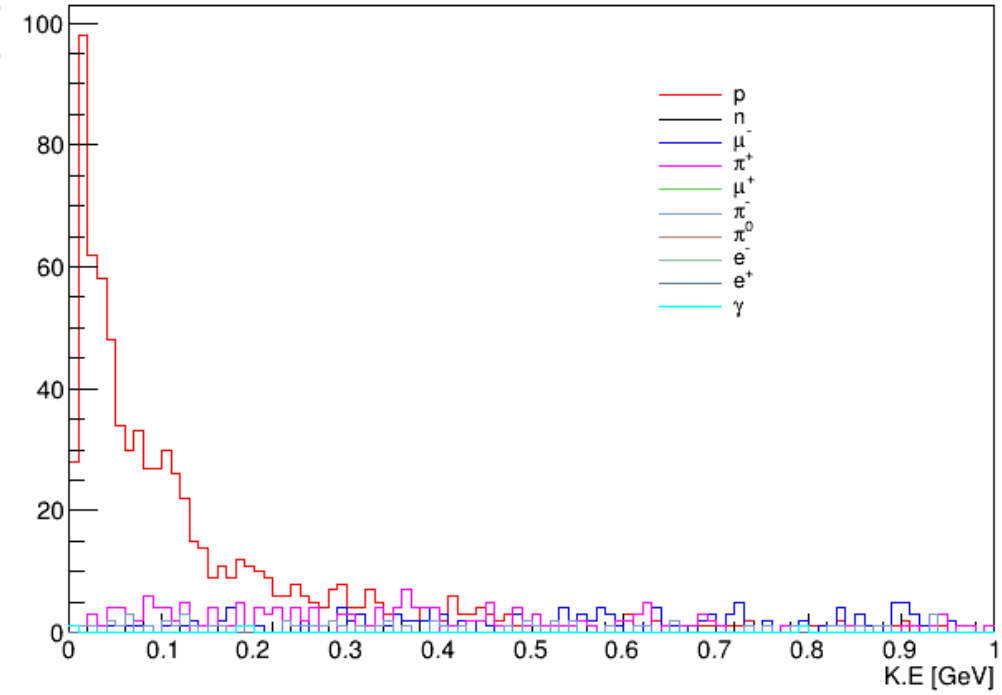




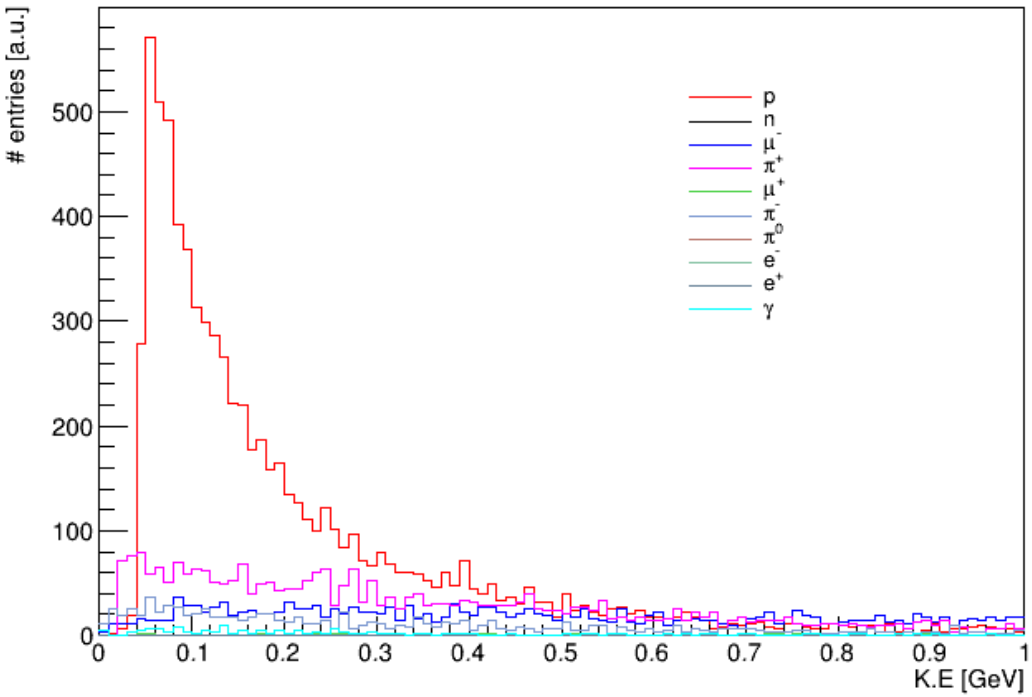
Detection Thresholds

- Threshold of 2 cm applied to both LAr and HPg TPCs

HPgTPC



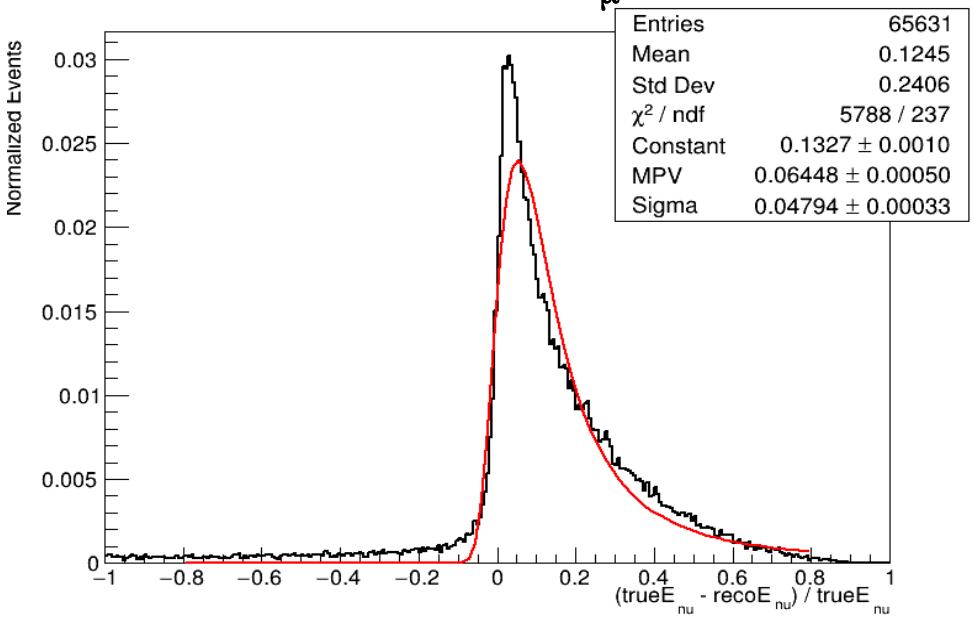
LAr TPC



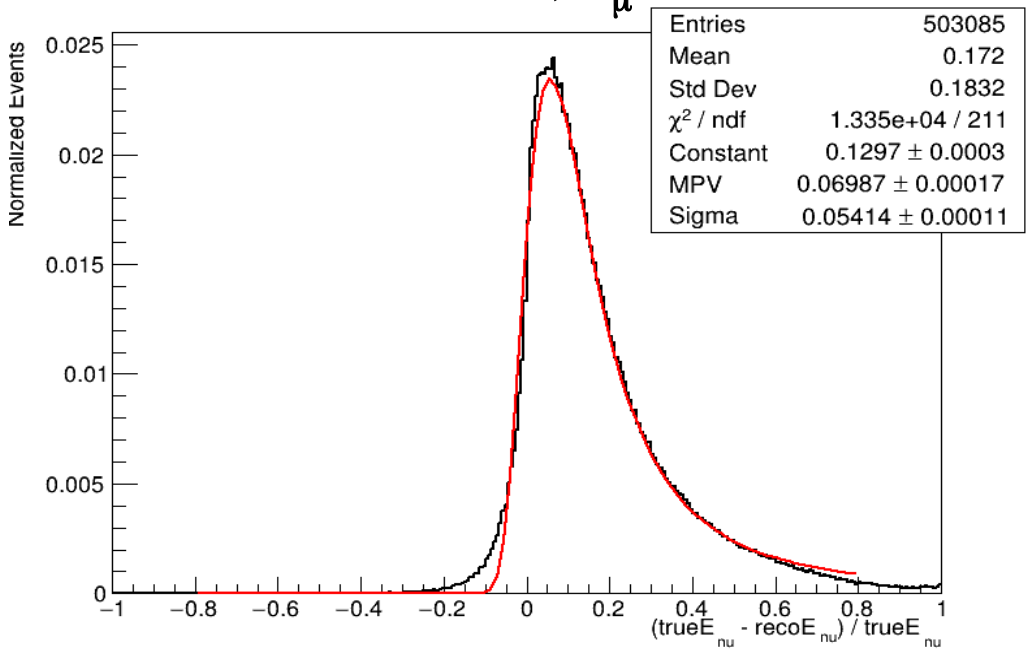
Updated ν-Energy Reconstruction

- ν-energy reconstruction via a particle-by-particle approach in both HPgTPC and LAr TPC edepsim reco
  - ★ Naively, assume we correctly identify pions 100% of the time in HPgTPC and in LArTPC and add pion mass into RecoEnu for both TPCs
- For now, used the truth level ν_μ CC interactions

HPgTPC, ν_μ CC



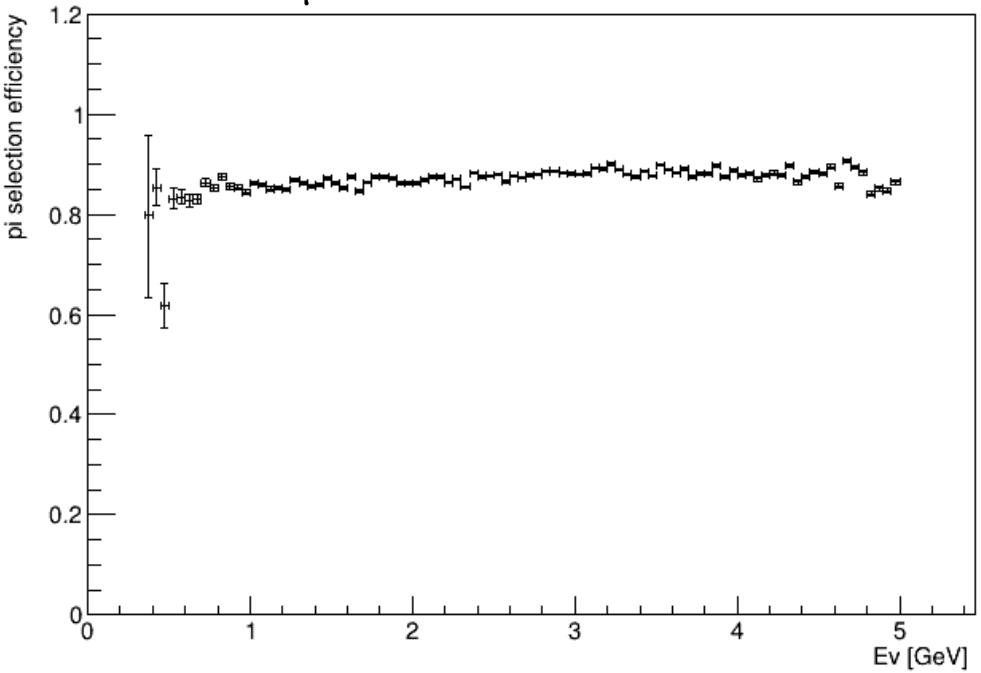
LAr TPC, ν_μ CC



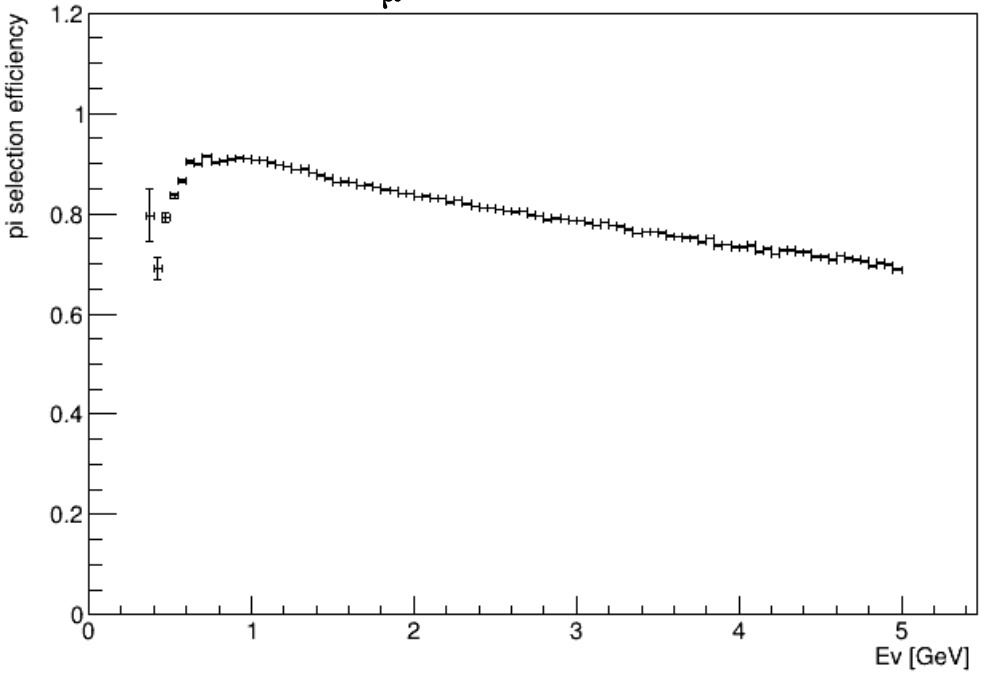
Pion Selection Efficiency – GAr vs LAr

- π selection in HPgTPC:
  - Naively assume we get π 100% right for all momenta except momenta below HPgTPC detection threshold (> 2 cm tracklength, ~< 5 MeV)
  - Sign tagging is only possible in HPgTPC because of magnetization
- π selection in LAr TPC:
  - Also naively assume that we get π 100% right for all momenta except momenta below LAr TPC detection threshold (> 2 cm tracklength, ~< 40 MeV)

HPgTPC, ν_μ CC 1π selection efficiency



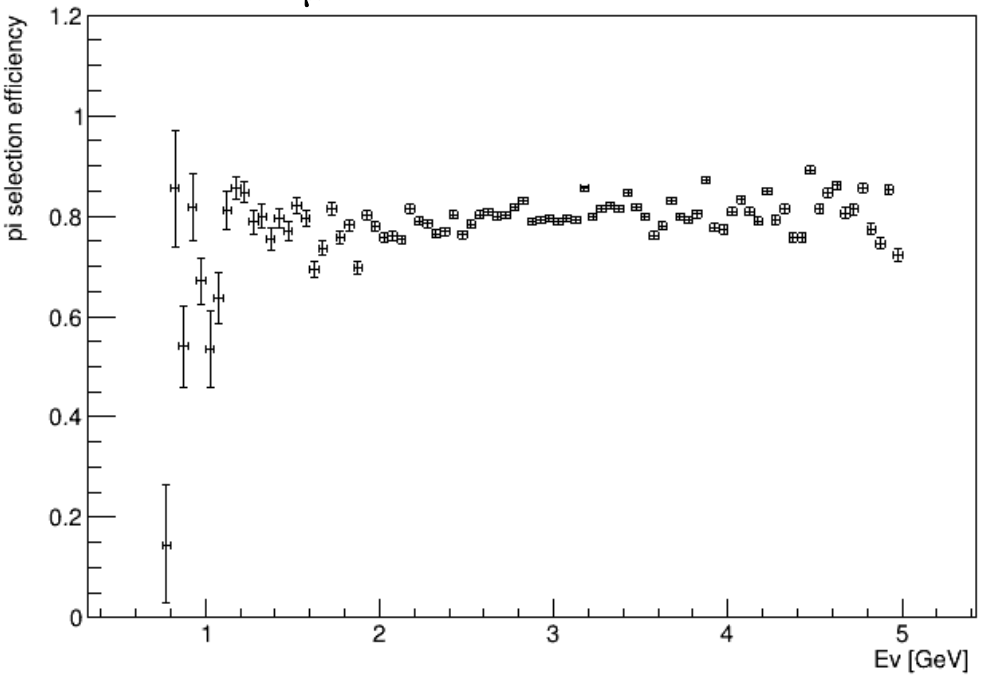
LAr TPC, ν_μ CC 1π selection efficiency



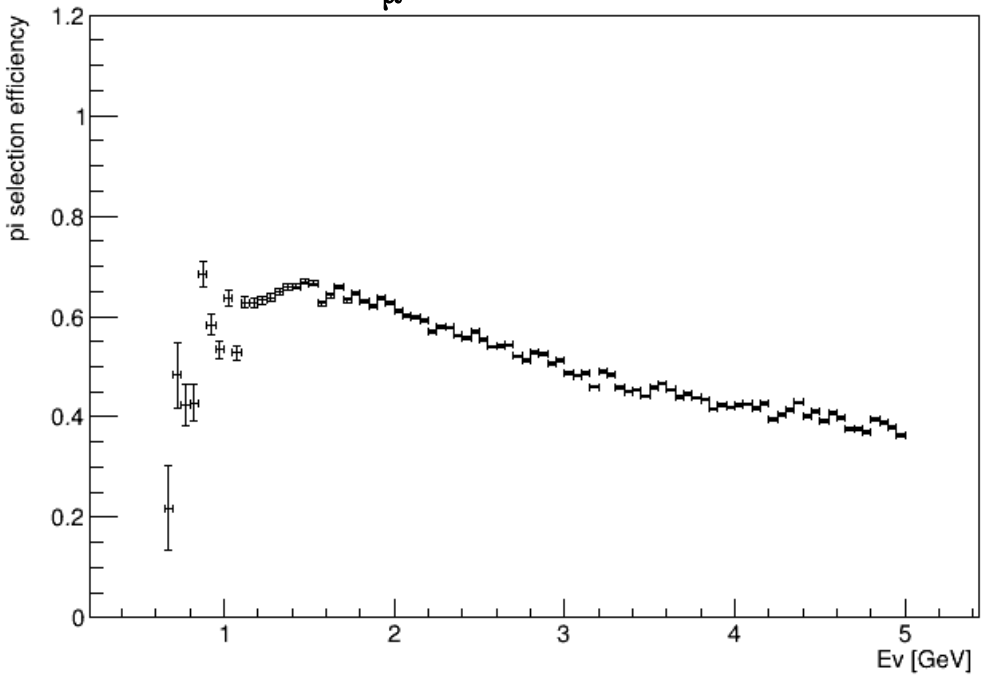
Pion Selection Efficiency – GAr vs LAr

- What do we learn from 1 π and 2 π selection efficiencies in HPgTPC and LArTPC:
  - ★ At first oscillation maximum (~2.5 GeV Ev), HPgTPC does a better job at reconstructing pions (likely low energy pions below LArTPC detection threshold) than LArTPC

HPgTPC, ν_μ CC 2π selection efficiency



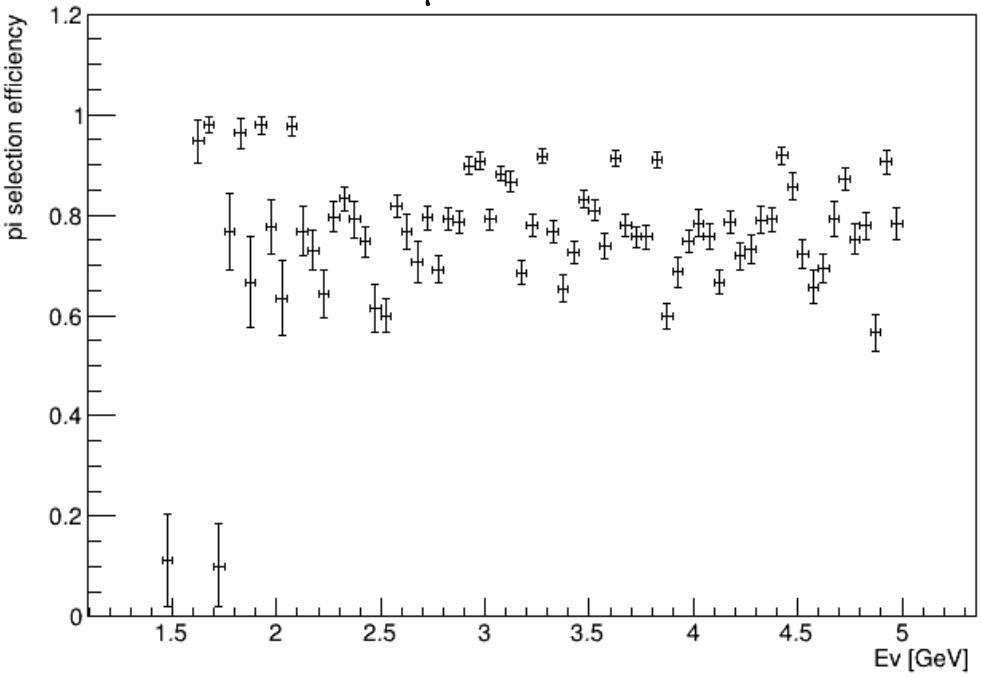
LAr TPC, ν_μ CC 2π selection efficiency



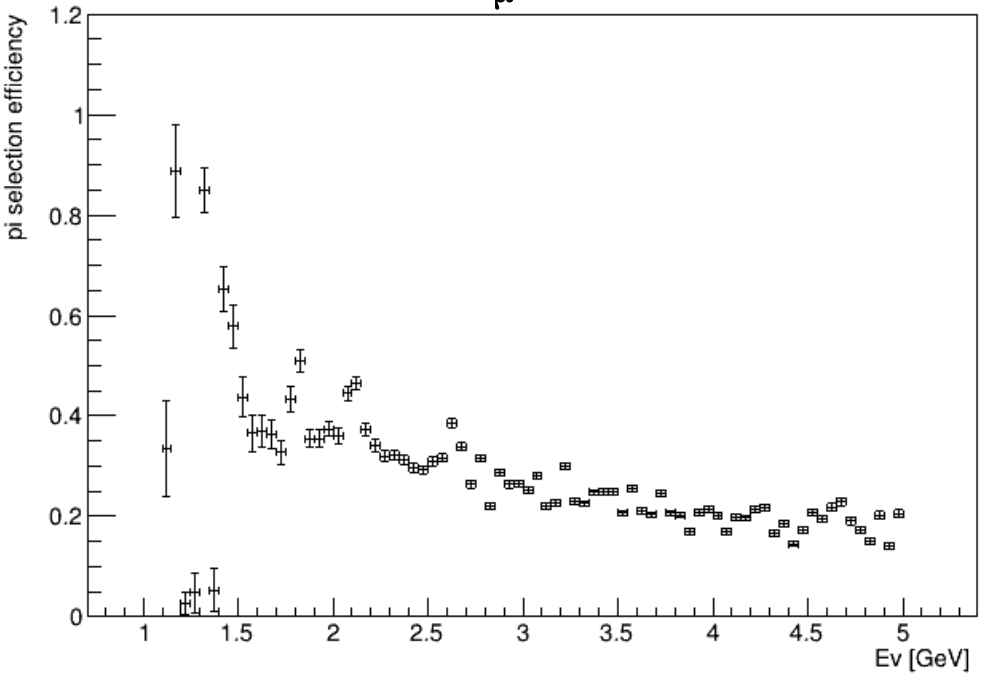
Pion Selection Efficiency – GAr vs LAr

- What do we learn from > 2 π selection efficiencies in HPgTPC and LArTPC:
  - Again, at first oscillation maximum (~2.5 GeV Ev), HPgTPC does a better job at reconstructing the three low energy primary pions that emerge from a neutrino interaction (likely these are pions below LArTPC detection threshold) than LArTPC

HPgTPC, ν_μ CC > 2π selection



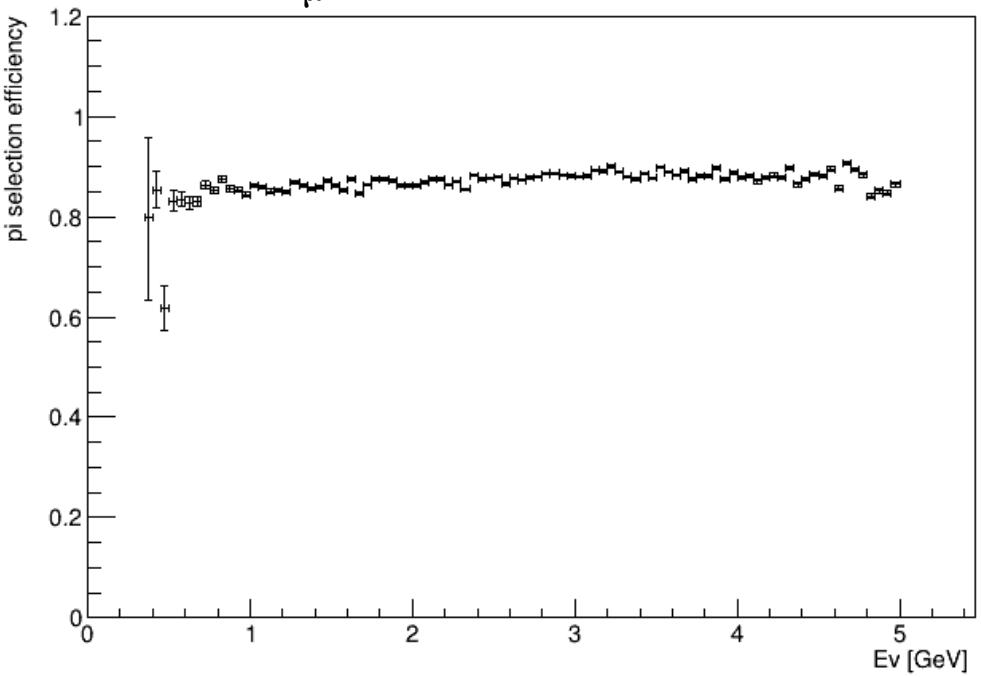
LAr TPC, ν_μ CC > 2π selection



Pion Selection Efficiency – Sign Tagging in GAr

- π+/– selection in HPgTPC:
  - ★ Unlike LArTPC, in HPgTPC, we can do sign tagging; in FHC running mode, we can select both π+ and π–

HPgTPC, ν_μ CC 1π+ selection



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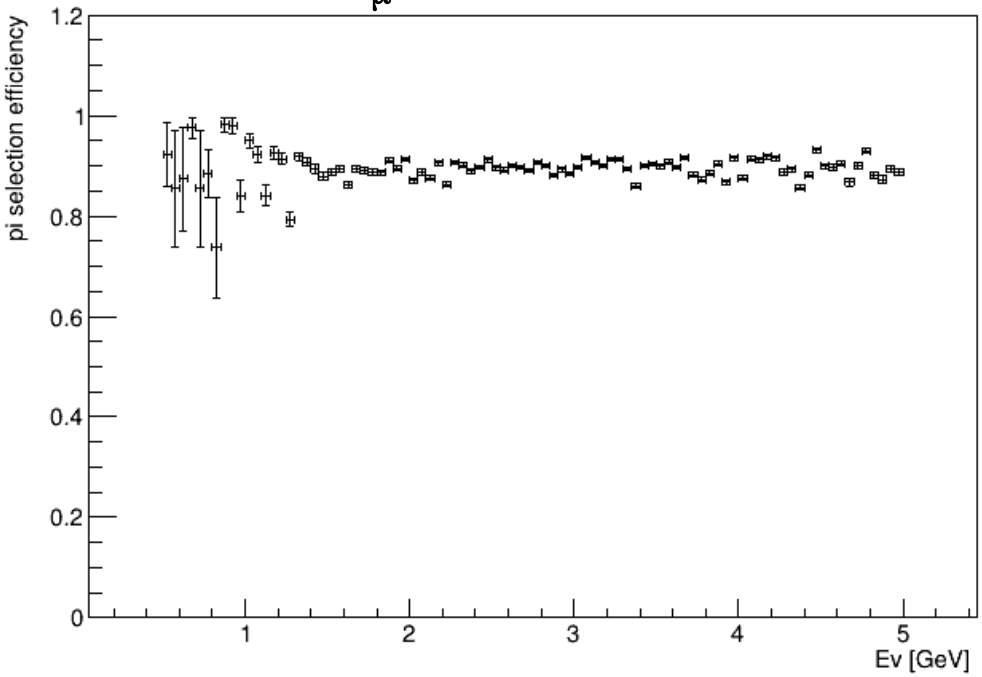

Summary

- Comparison between the LAr TPC and HPgTPC samples following the latest modifications to the edepsim parametrized reconstruction is now done on an apple-to-apple basis
- A preliminary analysis of the edepsim samples indicates HPgTPC can be advantageous over LAr TPC in the following:
  - Selection of lower energy final state pions (given the lower energy detection threshold in HPgTPC)
  - Reconstructing the neutrino energy

Next Steps

- The TEA parametrized reco is advantageous in the sense that it is a lot more realistic in reconstructing pions but it is not integrated with an equivalent LAr TPC parametrized reconstruction (a more realistic parametrization of LAr TPC does not exist)
- Some level of work can be done on the edepsim parametrized reco (**if as a group we think this is worth getting into? I guess a question for Steve M. and Mike K.**) to bring it up to speed with the TEA parametrized reco:
  - Generate new edepsim samples using the TEA GENIE files and TEA geometry
  - Update the HPgTPC parametrized PID using Tom's parametrization of PIP-II dE/dx – the only caveat is that we would need a volunteer to do the same for LArTPC

Pion Selection Efficiency – Sign Tagging in GAr

- π+/– selection in HPgTPC:
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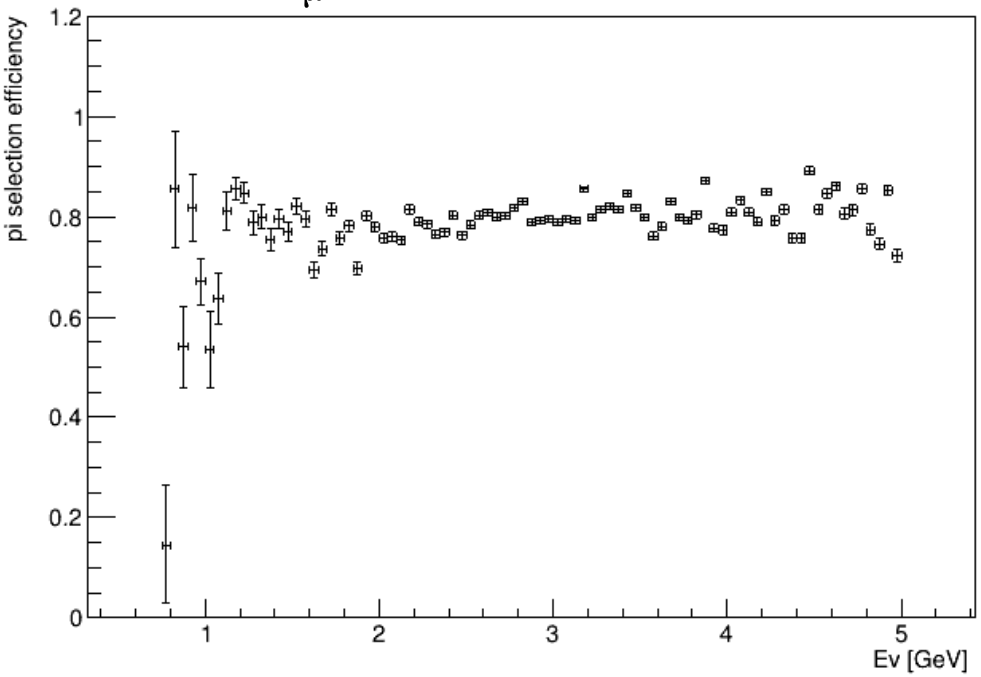
HPgTPC, ν_μ CC 2π+ selection



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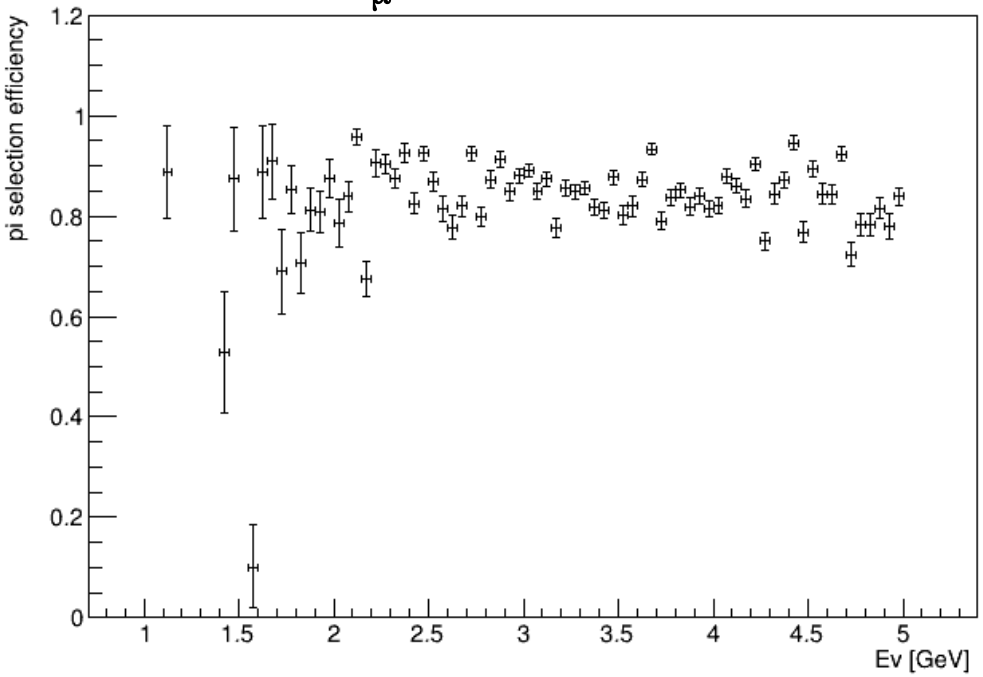

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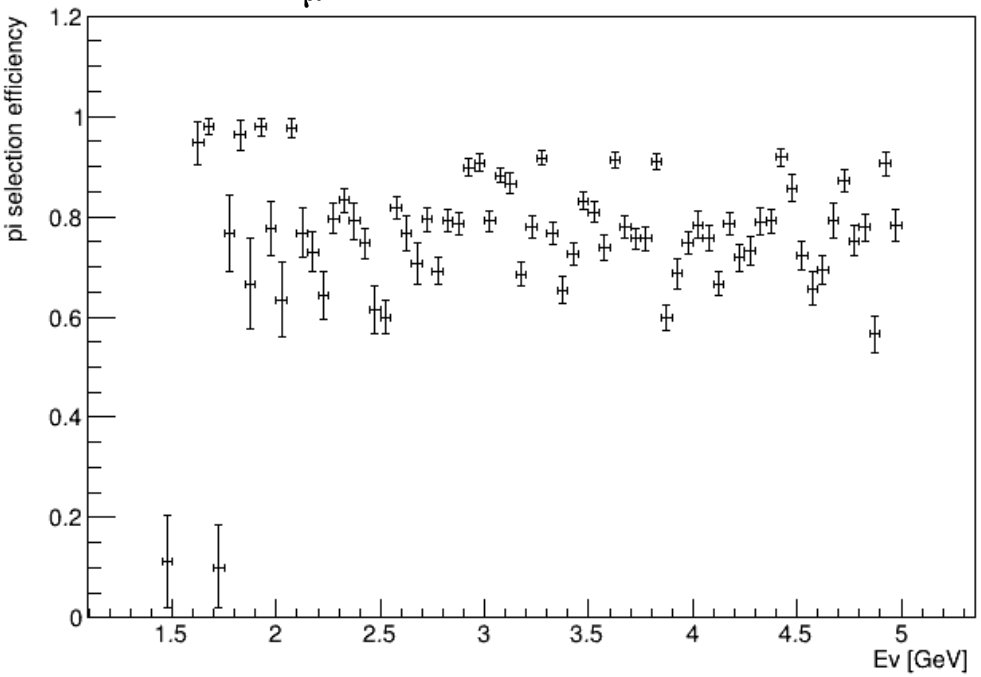

HPgTPC, ν_μ CC >2π– selection